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Analysis of the operational characteristics of the main units of BelAZ vehicles in a coal mine

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Abstract. A comparative analysis of the operational characteristics of the main components of BELAZ mining vehicles has been carried out. It is shown that the choice of type and means of career transport is determined by a number of factors and, first of all, by the characteristics of the transported cargo, the distance of transportation, the scale of work and the pace of their development. The power of vehicles depends on the scale of work (freight turnover), and the pace of mining operations determines the requirements for the operational reliability of career vehicles. The dependence of the dump truck failure parameter on the service life is disclosed. The analysis of the state of metal structures of structural elements of the dump truck BELAZ-7530 based on the method of non-destructive testing is given. As a result of the analysis of thermal imaging and measurements of the thickness of the walls of the motor housing, it was established that the amount of wear depends on the heating temperature of the metal structures.

1. Introduction

The growth of an open method for developing mineral deposits is accompanied by an increase in the scale of production and transportation of rock mass, an increase in the depth of the quarries, an increase in the share of semi-rock and rock rocks, and the complication mining and technical conditions exploitation of mining equipment [1].

At the turn of the XXI century, the main type of technological transport in the mining of minerals by the open method is road transport. So, in the USA and Canada, the share of road transport is 85%, in South America - about 85%, in Australia - about 100%, in South Africa more than 90%, in Russia and the CIS countries - 75%, and in the near future will increase due to the expansion of the open method of coal mining in Russia and Kazakhstan.

The dominant position of career vehicles is due to the indisputable advantages inherent in it, such as mobility, flexibility, autonomy, the ability to ensure high intensity of mining operations. That is why the leading machine-building companies producing dozens of models of dump trucks and their modifications with load capacities from 25 to 360 tons are engaged in the production of mining dump trucks in the USA and Japan. But the largest producer of heavy dump trucks is BelAZ JSC, which accounts for 33% of the global market products.



2. The purpose and objectives of the study

The purpose of the study is to improve the performance characteristics of career vehicles.

Objectives of the study:

- analysis of the operational performance of career vehicles;
- identifying the problems of the technical condition of metal elements of the quarry vehicles;
- justification of directions for improving the design elements of career vehicles using non-destructive testing.

3. Solving research problems

The object of study - the constructive elements of career vehicles.

O The subject of the research is the determination of the operational reliability of career vehicles, the interrelationships between the failure parameters and the service life, the wear value and the heating temperature of the steel structures.

Research methods - analysis of the results of scientific studies to determine the parameters of failures, the use of non-destructive testing based on thermal imaging.

Career transport has a number of features that distinguish it from public transport [1-11]:

1. The points of loading and unloading constantly change their position, following the front of mining, which requires periodic movement of transport communications and equipment (railways, roads, conveyors).

2. The cycle of career vehicles of periodical action (rail, road, etc.) consists of loading, motion with cargo, unloading and returning empty.

3. Transportation from a quarry occurs, as a rule, on a large slope when developing both deep and highland deposits.

4. For productive use of mining and transport equipment (excavators and rolling stock) it is necessary to coordinate their parameters. The main requirements for career transport are: ensuring a given freight turnover; uninterrupted operation (exact adherence to the schedule - for cyclical means and continuity of flow - for vehicles of continuous action); perhaps less labor intensive work (due to the use of mechanization and automation of the main and auxiliary processes during transportation); traffic safety and work management. One of the main provisions when choosing transportation schemes is the separation of cargo traffic of overburden and mineral resources, which is expedient, for example, in conditions of large and medium production capacity of quarries (if geological conditions allow), as it ensures the rhythmic and smooth operation of the entire enterprise. The choice of type and means of career transport is determined by a number of factors and, first of all, the characteristics of the transported cargo, the distance of transportation, the scale of work and the pace of their development. The power of vehicles depends on the scale of work (freight turnover), and the pace of mining operations determines the requirements for the operational reliability of career vehicles.

The functional criterion for the use of career transport is productivity, which is directly influenced by the technical condition of the machines and external factors (climatic conditions, production organization, etc.). Career transport is operated in a wide variety of climatic, geological and road conditions. Most of the coal mines are located in areas of sharply continental climate: low, down to minus 40 ° C and lower, temperatures in winter with strong winds and high temperatures in summer (up to 40 ° C).

The main mining vehicles today and in the near future are classic diesel engine dump trucks in combination with either a hydromechanical or electromechanical transmission with a 4x2 wheel arrangement.

The work specifics vehicles should include the predominance of instable traffic patterns and a significant proportion (up to 40-50%) of loading and unloading and shunting operations in the total duration of the transport cycle. In addition, for dump trucks working on assembly transportation, there is an under-utilization of speed, a 25-40% increase in the specific consumption of diesel fuel and tires, less reliability and mileage (by 25-30%).

The work of dump trucks on the main transportations is characterized by a significant lifting height (up to 120-160 m and more) and a transportation distance (up to 4.2-4.8 km) with high values of weighted average gradients on the road (3.5-5.5%). The latter indicator is complex, most fully reflecting the complication of the operating conditions of the main transport with an increase in the depth of the quarry.

The increasing complexity of operating conditions with an increase in the depth of mining of the open pit leads to a decrease in the productivity of vehicles and an increase in transportation costs. The share of transport in the cost of mining of deep quarries reaches 55-70%.

Finding dump trucks to be repaired at coal mining enterprises amounts to 20...25% of the calendar time fund. The existing system of maintenance and repair of mining trucks is characterized by the fact that out of 8760...8784 hours of the annual calendar fund, productive time averages 2500 ... 3500 hours, while for 1 hour of productive work of dump trucks, the downtime for repairs varies from 0.4...1.2 hours.

The high cost of heavy vehicles makes it costly every hour of expectations repair and repaired, therefore the efficiency of using these machines is largely determined by the level of training of the maintenance personnel and the organization of maintenance and repair work, as well as the state and development of the production base of the open pit fleets.

Dump trucks are operated in a highly dynamic environment. As the mineral resource is mined, the quarry space is rebuilt in terms of volumes, directions, and time, slopes, curvature of roads, transportation distances change, and changes in geological conditions create prerequisites for disturbing the stability of resource flows. Constantly changing conditions of the functioning of vehicles contribute to changing the load on the nodes and parts of dump trucks, and, consequently, the flow of failures.

The loss of time for career vehicles associated with unproductive work is largely due to the state of the processes of the technical operation of the dump trucks, since failures due to poor maintenance and repair have a significant effect on the regularity and stability of the operation of dump trucks and, consequently, onto the operational reliability and efficiency of using these machines.

When building a mathematical model of the aging dynamics of the BelAZ-7530 cars with a carrying capacity of 220 tons, the premise of independence of output parameters was adopted, through which the change in the failure parameter $\lambda(t)$ during the operation of dump trucks was considered separately, since this parameter most fully reflects the aging dynamics [2].

As a result of research, a curve of change in the failure parameter $\lambda(t)$ was constructed depending on the service life t , which can be approximated by the dependence:

$$\lambda(t) = 2,2 \cdot 10^{-9}t^2 + 0,078 \quad (1)$$

that is, the risk of failures monotonously increases in the process of long-term operation of the machine (Figure 1).

Suppose that the flow of failures proceeds according to the Poisson law, then the probability that a failure does not happen during time t is equal to $P(t) = e^{-\lambda t}$.

Given the increase in the failure rate with the operating time, we get:

$$P(t) = e^{-2,2 \cdot 10^{-9}t^2 - 0,078t} \quad (2)$$

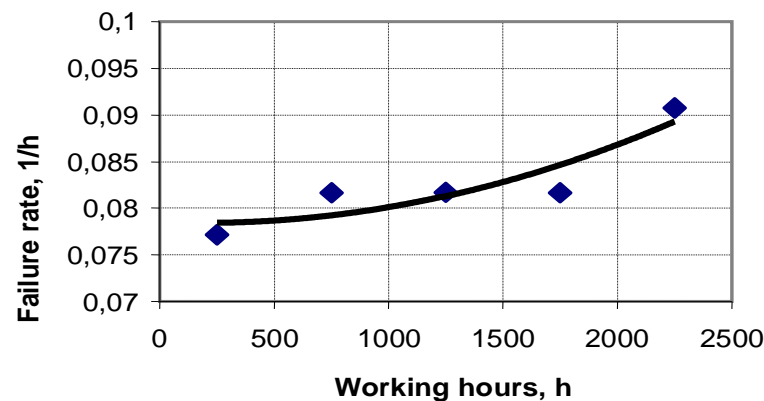


Figure 1. Dependence of the failure parameter $\lambda(t)$ of BelAZ-7530 dump trucks on the service life t . From here, the average lifetime of an item of a dump truck construction is:

$$T_{exp} = \int_0^{\infty} P(t) dt = \int_0^{\infty} e^{-2.2 \cdot 10^{-9} t^3 - 0.078 t} dt \approx 12.8h \quad (3)$$

The equation by which we determine the average lifetime of a structural element with regard to its aging is a mathematical model of the dynamics of aging of BelAZ-7530 dump trucks with a carrying capacity of 220 tons. Knowing the average lifetime of a dump truck, you can plan maintenance and repair of the machine as a whole, and develop repair standards taking into account the dynamics of its aging.

In most cases, during the examination of the metal structures of the main assemblies of BELAZ vehicles, including the metal structures of the front wheel, engine, rear axle, and motor wheel (figure 2-5), in order to extend the life of the vehicle as a whole, only visual defects are taken into account: cracks, loosening of parts, lack of protective covers, etc. However, visual measuring control can only very closely assess the current state of metal structures and determine the residual life of the entire design of the dump truck. As a rule, during the subsequent operation of such equipment, destruction of metal structures is often observed. Therefore, during the examination of metal structures, non-destructive testing methods are widely used, which, together with the visual measuring control, make it possible to accurately determine the technical state of metal structures and predict the residual life.

Typical equipment, such as compressors, heat exchangers, cooling fans, pumps, motors, as well as mechanical equipment, such as belts and bearings, can be checked with a thermal imager. Temperature differences and abnormal temperatures that cannot be attributed to the working load of the equipment usually indicate a malfunction or the possibility of its occurrence.

Evaluation of the technical condition of the front wheel, engine, rear axle, motor-wheel is made on the basis of the analysis of technical maintenance documentation, repair logs, based on the experience of previous operation, the frequency of replacement of worn nodes. A visual inspection of the assemblies, instrumental measurements, non-destructive testing of some elements of the metal structure were carried out.

An analysis of the durability of the material of the structural elements of the front wheel, engine, rear axle, motor wheel, and operating experience of dump trucks has shown that one of the factors affecting the performance of the front wheel, engine, rear axle, and motor wheel is the elevated temperature that occurs when an incorrect operating a dump truck [1-11].

According to the results of thermal imaging of the front wheel, engine, rear axle, motor wheel with a CONDROL IR-CAM 2 thermal imager (a new generation thermal imager that combines professional features and functionality with ease of operation and a simple interface similar to the phone menu), the highest temperature observed at the engine - 122 0C (figure 2-5).

CONDROL IR-CAM 2 has 2 cameras, one of which works like a normal camera, and the second in the infrared range and allows you to superimpose images from two cameras with 5 gradations. The model has a mode for automatically determining the minimum and maximum temperature values on

the screen. The choice of gradient color scales allows you to adapt the image on the screen for different working conditions, and an adjustable emission factor allows you to control the temperature when working with different materials and colors of the metal.

Measurements of the wall thickness of the sections with a TT-260 thickness gauge showed that the average actual thickness of the engine body is 5.6 mm with the manufacturer's installed thickness of 8 mm (Table 1).

The actual wear on the size of the wall of the motor housing is determined by the expression:

$$\tau = (h - h_f) \cdot 100\% \quad (4)$$

where: h - the original thickness of the wall of the case, laid down by the manufacturer, mm; h_f - actual wall thickness, mm.

The results of calculations of wear by the size of the walls of the engine housing showed that the average wear of the walls is 44.6% (Table 1).

As a result of the analysis of thermal imaging and measurements of the thickness of the walls of the motor housing, it was established that the amount of wear depends on the heating temperature of the metal structures.

Table 1. The results of measuring the thickness of the walls of the dump truck construction elements

№	Element	Wall thickness, mm		Maximum allowable wear, mm	Wear by size, %	Duration of use before destruction, months
		Fact.	Factory-made.			
1	Housing engine	5.4	8.0	2.0	46	30.4
2	Front wheel	5.12	8.0	2.0	48.8	26.01
3	Rear bridge	5.4	8.0	2.0	46.1	38.8
4	Motor-wheel	5.3	8.0	2.0	46.8	28.8
Average value		5.3	8.0	2.0	46.9	31.025

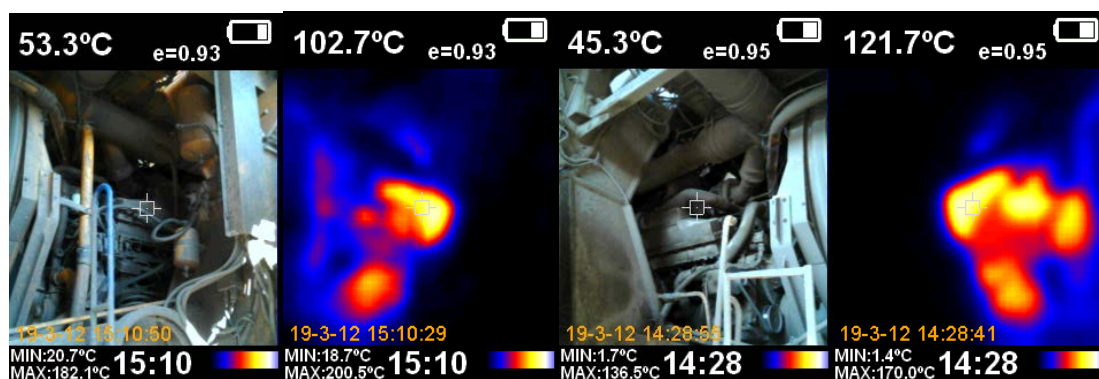


Figure 2. Engine before lifting

Figure 3. Engine after lifting

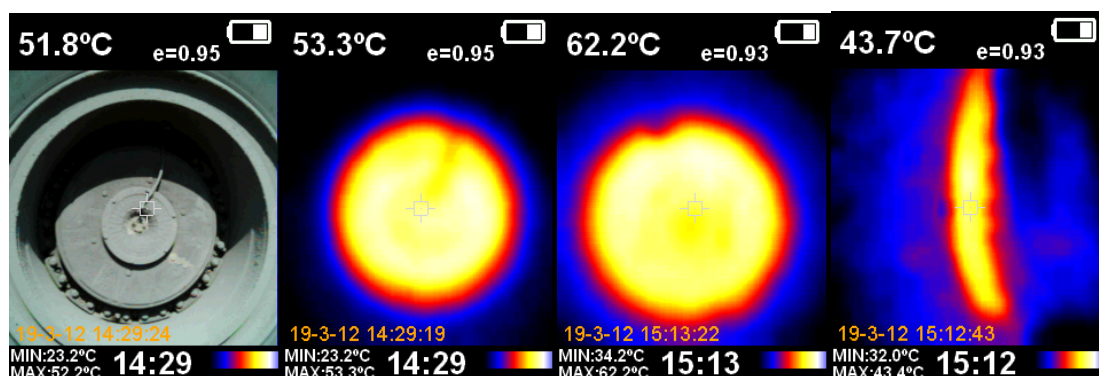


Figure 4. Motor-wheel reducer from the front, side, from the inside (BelAZ after lifting)

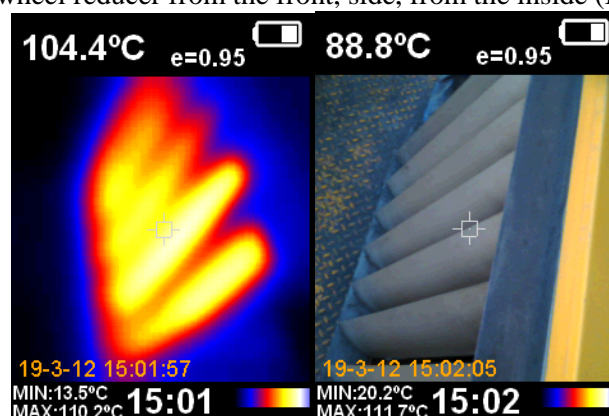


Figure 5. Electrodynamic brake resistor after lifting with load

Considering that the degree of average wear of the engine housing walls 46.9 % was reached within 30 months, then under the existing conditions of operation of the dump truck, complete destruction is determined by the expression:

$$T = \left(t \cdot \frac{h - h_p}{h - h_f} \right) - t, \text{ months} \quad (5)$$

where: $t = 20$ months - service life; $h_p = 2$ mm is the wall thickness of the engine block at which destruction will occur.

As a result of the assessment of the technical condition of the walls of the engine casing, it was established that the average wear of the walls of the elements of metal structures is 46.9 % and the service life until structural failure is 31.025 months

Thus, the assessment of the technical condition of the metalwork of the front wheel, engine, rear axle, motor-wheel using measuring and non-destructive testing allows determining the most worn elements with the possibility of further identifying the causes of increased wear and developing recommendations for their elimination. The main cause of engine metal wear is high temperature, which leads to an increase in wear rate during gas corrosion.

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